Evaluation of Suitability of Selected Dredged Sand and Sludge for Engineering Application

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Abstract

This paper investigates the possibility of using sludge as alternative to sharp sand in concrete production. Sludge was obtained from the burrow pit and dewatered on the site. The obtained samples were tested in the laboratory for moisture content, particle size distribution and silt/clay content. Concrete produced was tested for water absorption, density and shrinkage. Also, compressive strength of concrete was determined using compression machine. The obtained results showed that sand and sludge have moisture contents of 22.22% and 111% respectively. The percentage of clay in the sand was 2.78% and that of sludge is 77.78%. The particle size distribution classified the sand into well graded and the poorly graded sludge kind. Results showed that sand has a pH of 7.78 and that of sludge is 5.32. Compressive strength of concrete produced from sand varied from 10.11N/mm^2, 11.78N/mm^2, 17.04N/mm^2 and 21.78N/mm^2 cured for 7, 14, 21 and 28 days respectively and concretes produced from sludge varied from 2.03N/mm^2, 3.63N/mm^2, 9.70N/mm^2 and 12.52 N/mm^2 cured for 7, 14, 21 and 28 days respectively. It was discovered that compressive strength of concrete produced from sand is higher than 21 N/mm^2 and that of sludge is lower, hence, sludge is suitable for production of bricks.

Keywords

Dredging; Sand; Bricks; Concrete; Sludge; Engineering

Introduction

In the past few decades, the rapid process of dredging activities has increased the generation of waste materials (Sludge) at tremendous rates, and disposal of this waste has posed a problem. It has also become extremely costly due to the scarcity of land and the growing concern on the environment (environment hazards such as pollution and scare due to urbanization). This situation has raised alarming concerns over many municipalities, particularly in densely populated areas. There is also a strong demand for environmentally safe reuse for sludge due to the increasing amount of generated sludge during sand production which is also known as dredging. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. Dredged sand has sharp, un-weathered edges that make it gritty and appropriate for mixing concrete. Sharp sand is used as a soil amendment, makes tight soils looser and gets a lot of use in bonsai cultivation (art of growing miniature trees). Dredged sludge (mixture of clay and silt in the major portion as well as sand and gravels in lower proportion) is considered as a waste which is subjected to a specific waste policy. It is the fact that both the quantity and quality can vary significantly depending on local factors. Sludge itself is typically 95 -99% water at its point of production with 1–5% solid constituents (Snow, 1996). Classification of the sludge depends on its origin and on its composition: type A stands for unpolluted or slightly polluted sludge while type B for the other categories (Vandorpe, 2005). Type A sludge can be recycled on site or via “grouping centres” whereas type B sludge is oriented to pre-treatment centres to re-classify them as type A or is oriented to a “grouping centres” for treatment and further elimination such as cement. Also, current sludge regulations limits sludge disposal alternatives based on the provided treatment level provided, pathogen removal, and metals content. At the same time, practical disposal options for sludge involve some form of environmentally safe reuse of the product, whether by thickening, stabilization (aerobically or anaerobically), composting, or pelletizing. Therefore, using sludge to produce construction and building materials has been one of the few alternatives available for disposal of sludge. Converting the sludge into useful products would alleviate the problems of waste disposal while

providing a new reserve for the depleting resources of construction materials.

As a result, the focus of "reuse" of dredged waste products should not be solely limited to the use of reclaimed water, but it can also be employed to turn by-products into useful materials like the construction materials. In view of the anticipated disposal problem of sludge and associated environmental concerns, recycling of sludge into useful materials is gaining due consideration as an alternative disposal option. Over the years, many studies have been carried out on the use of industrial and municipal sludge for innovative construction materials. Alleman and Berman (1984) and Tay (1985) used sludge in combination with clay to produce building bricks of normal strength, and Tay (1987) also reported that sludge could also be used as cement filler. The objectives of this paper are to determine engineering properties of sludge and dredged sand, engineering properties (mechanical and physical properties) of concrete produced from dredged sand and sludge, and its suitability for construction. It was observed that during the raining season in Nigeria there is little or no recovery of sharp sand in the course of dredging which will increase its cost. More importantly, based on the observed facts that recovery of sludge is higher during raining season, this study will confirm whether sludge could be a substitute for sharp sand at this time of the year.

Materials and Methods

The study area is the Construction Support Nigeria limited site located at Construction Support Close Majidun, Ikorodu West Local Government Area of Lagos State. The sand and the sludge were dredged from the burrow pit. The burrow pit is located at latitude 6^0 28′ 31″N and longitude 3^0 26′ 24″ E on the Atlantic Ocean and the study area is presented in FIG. 1.

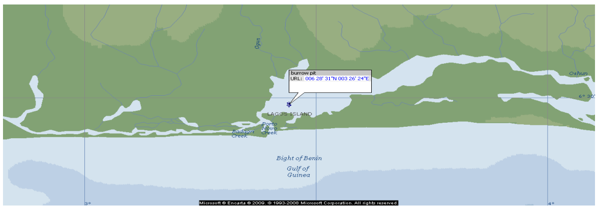

FIG.1 LOCATION OF BURROW PIT

The required materials are cement, water, aggregates (fine and coarse aggregates), sand and sludge. The sand was collected from the stock pile where it was deposited on the site after being transported from the burrow pit which is also known as the dredging area. The sludge was collected from the bucket on the dredger and on-site dewatering process was carried out with the aid of the dewatering apparatus.

Sludge

The collected sludge was in black colour. The water-filled sludge was collected on the dredger and immediately dewatered using the on-site dewatering equipment. The dewatered sludge was broken into smaller sizes and then sun-dried spreading them on the sacks. Some smaller quantity was washed and oven-dried as shown in PLATE 1.

PLATE 1 SLUDGE SAMPLE

Mix Design Process for Production of Construction Materials

A wooden formwork of size 150mm X 150mm X 150mm was used to cast concrete cubes. Only one used concrete mixture is the 1:2:4. For the investigation of the suitability of dredged sand and sludge, two concrete mixtures of 12 cubes were made alternating fine aggregates as sand and sludge and they were all studied

(a) Portland cement, granite, water and Sand Control Mix)

(b) Portland cement, granite, water and sludge

The weight of used samples are presented in TABLES 1 and 2 for the concrete mix

TABLE 1 DESIGN MIX RATIO AND WEIGHT

Sample	Sand	Sludge
Ratio	1:2:4	1:2:4
Weight of Cement (kg)	13	13
Weight of Water (kg)	8.45	8.45
Weight of Coarse Aggregate {Granite} (kg)	52	52
Weight of Fine Aggregate	26	26

TABLE 2 SUMMARY OF CONCRETE CUBE LAYOUT

Group Description	Mixture	Age	Total No. of Cubes
A	Cement, Sand, Water, Gravel	7 14 21 28	3 3 3 3
B	Cement, Dried-Sludge, Water, Gravel	7 14 21 28	3 3 3 3
TOTAL			24

Determination of Moisture Content

The moisture content was determined using Equation 1 and the results are presented in TABLE 3 for sand and sludge respectively and the procedure is in line with ASTM 1998 D2216.

$$\text{Moisture content} = \frac{W_3 - W_2}{W_2 - W_1} \text{ X } 100 \text{ ....1}$$

Where, W_3 is Mass of wet sand or sludge, W_2 is Mass of dry sand or sludge and W_1 is Mass of empty can.

Determination of the Chemical Composition of Dredged Sand and Sludge

The chemical composition was determined in accordance with the British Standard 1377 (1975) test procedures for soil. The results are presented in TABLE 4 for both sand and sludge.

Determination of pH of Samples

The electrode of the pH meter which has been washed with distilled water was immersed in the soil suspension and reading taken and the results are presented in TABLE 4 for both sand and sludge.

Determination of Percentage Silt/Clay Content

In the experiment, a soil-water mixture is shaken and allowed to be settled, which enables estimation of the relative proportions of each size class. The clay will settle above the silt and the height of the silt layer (in mm) can be expressed as a percentage height of the below silt (in mm). The silt/clay content was determined using Equation 2 and the results presented in TABLE 5.

$$\%\text{Silt/Clay Content} = \frac{\text{Lenght of Upper Part}}{\text{Total Lenght}} \text{ x } 100\text{.................2}$$

Particle Size Distribution

Particle size distribution consists of quantified size classes by percentages based on weight from the graphical results of the grain size analysis (ASTM 1963).

Determination of Compacting Factor

The compaction factor test was carried out on the samples. The compacting factor (C.f) was determined using Equation 3 and the results are presented in TABLE 6

$$\text{C.f} = \frac{\text{weight of partically compacted concrete}}{\text{weight of fully compacted concrete}}\text{.............................3}$$

Determination of Water Absorption Capacity

The water absorption capacity was determined using Equation 4 and the results are presented in TABLE 7 for both sand and sludge concrete.

$$\text{Water Absorption} = \frac{W_2 - W_1}{W_2} \text{ x } 100 \text{ ....4}$$

Where W_1 = dry sample mass (kg)

W_2 = saturated sample mass (kg)

Determination of Compressive Strength

The compressive strength was determined using Equation 5 for both sand and sludge concrete respectively.

$$\text{Compressive strength} = \frac{\text{Crushing Load}}{\text{Area of cube}} \text{ ....5}$$

Determination of Linear Shrinkage

The Drying/linear shrinkage was determined using Equation 6 and the results are presented in TABLE 7 for both sand and sludge concrete respectively and the results are presented in TABLE 7.

$$\text{Linear shrinkage} = \frac{L_1 - L_2}{L_1} \text{ x } 100 \text{ ....6}$$

Where L_1 = Original length of sample

L_2 = Dried length of sample

Results and Discussion

The result of moisture content shows the sand has a moisture content of 22.22%, and sludge has a moisture content of 111%.

TABLE 3 MOISTURE CONTENT OF SAND AND SLUDGE

Material	Sand	Sludge
Average Weight of Can (g)	35.33	42.67
Average Weight of Wet material (g)	46.33	49.00
Actual Weight of Dry Material (g)	44.33	45.67
Moisture Content (%)	22.22	111

TABLE 4 presents the chemical composition of both sand and sludge respectively. It can be seen that sand has a basic pH 7.78 as shown in TABLE 4 which means a presence Alkali in the sand; therefore this means that an ordinary portland cement can be used in concrete making and suitable for construction. Thus treating sand with chemicals or stabilizers may be a waste. The organic matter in it is low. From the chemical analysis result in TABLE 4, it can be seen that sludge has an acidic pH 5.32 shows a presence of acid in the sludge, so it is recommended that a neutralizer be added if it is to be used. The organic matter in it is high.

TABLE 4 CHEMICAL COMPOSITION OF SAND AND SLUDGE

Material	pH	Carbon in Organic matter	Organic Matter	Nitrogen	Phosphorus
	In water 1:2	%	%	%	%
Sand	7.78	0.42	0.72	0.05	10.73
Sludge	5.32	0.56	0.82	0.08	10.83

Percentage Silt/Clay Content of Sample

The obtained result for sand has a low percentage of clay of 2.78% and high percentage of silt and sludge have high percentage of clay of 77.78% and low percentage of silt.

TABLE 5 SILT/CLAY CONTENT OF SAND AND SLUDGE

Sample	Length of Lower part (mm)	Length of Upper part (mm)	Total Length (mm)	Silt/Clay Content (%)
Sand	70	2	72	2.78
Sludge	20	70	90	77.78

Particle Size Distribution

FIG 2 shows the plot of the particle size distribution for sand. From the graph and comparing the obtained calculation result, it can be inferred that the sand is Well Graded Sand (SW) and this can be used in engineering constructions. FIG. 3 shows the graph of the particle size distribution for sludge. Since this sludge is classified as poorly graded sand with large amount of clay.

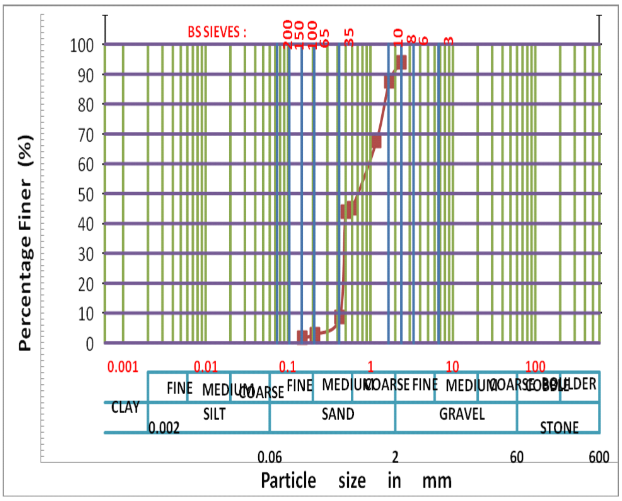

FIG. 2 PARTICLE SIZE DISTRIBUTION FOR SAND

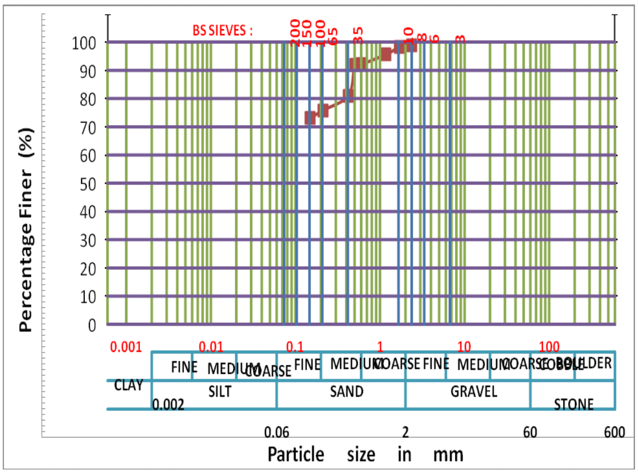

FIG. 3 PARTICLE SIZE DISTRIBUTION FOR SLUDGE

Compacting Factor Test

The results of the compacting factor test for both sand and sludge are presented in TABLE 6. According to (Wilby, 1990), compacting factor value obtained for sand and sludge concretes have very low workability.

TABLE 6 COMPACTING FACTOR FOR SAND AND SLUDGE CONCRETE

Sample	Weight of Partially compacted concrete (kg)	Weight of fully Compacted concrete (kg)	Compacting Factor
Sand Concrete	108.8	145	0.75
Sludge Concrete	120	153	0.784

Density of Concrete Cubes

FIG. 4 presents the plot of density against curing age. The results revealed that sludge concrete has a lower density value which is too low for it to be used as concrete therefore it may be used in production of block.

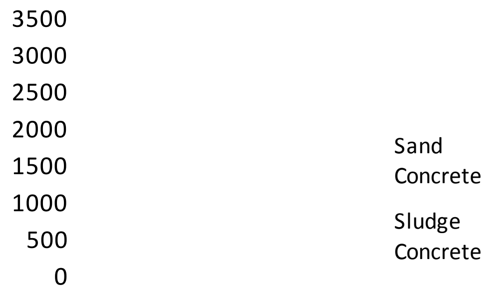

FIG. 4 DENSITY AGAINST AGE OF CURING FOR SAND AND SLUDGE CONCRETE

Compressive Strength of Concrete

FIG. 5 presents the plot of compressive strength against curing age. The results revealed that sludge concrete has a lower density value which is too low for it to be used as concrete therefore it may be used in production of block. This graph shows that as age curing increases the compressive strength increases as well. The minimum compressive strength for concrete is 21N/mm^2 at the age of 28days and that of sand concrete is higher with a value of 21.78 N/mm^2 therefore it is good for production of concrete. That of the sludge concrete is lower with a value of 12.52 N/mm^2 therefore it should not be used in making concrete but could be used for bricks or building blocks.

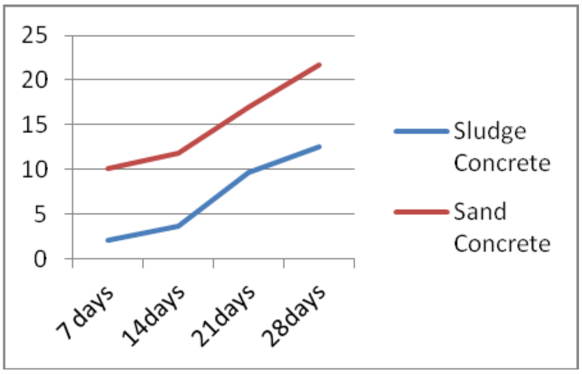

FIG. 5 COMPRESSIVE STRENGTH AGAINST AGE OF SAND AND SLUDGE CONCRETE SHRINKAGE AND WATER ABSORPTION CAPACITY OF CONCRETE CUBES

The results obtained for the water absorption capacity are presented in TABLE 7 for both the sand and sludge concrete. TABLE 7 shows that sand concrete cubes has a lower water absorption capacity of 2.4 and sludge concrete have a water absorption capacity of 11.11. Therefore it is better to use a material that has a lower water absorption capacity which is sand. In addition, it was observed that sludge concrete has shrinkage of 2.0%.

TABLE 7 SUMMARY OF WATER ABSORPTION CAPACITY AND SHRINKAGE OF CONCRETE

Sample	**Weight of dry sample (kg) W_1**	**Weight of Saturated Sample (kg) W_2**	**Water Absorp. Capacity**	**Original Length L_1 (mm)**	**Dried Length L_2 (mm)**	**Linear/ Drying Shrinkage (%)**
Sand Concrete 1	8.2	8.4	2.4	-	-	-
Sand Concrete 2	8.4	8.6	2.3	-	-	-
Sand Concrete 3	8.3	8.5	2.4	-	-	-
Average			2.4			-
Sludge Concrete 1	6.6	7.2	8.33	15	14.8	1.3
Sludge Concrete 2	6.8	7.2	14.7	15	14.7	2.0
Sludge Concrete 3	7.0	7.8	10.3	15	14.8	1.3
Average			11.11			2.0 (nearest whole number)

Conclusions

This had evaluated properties of dredged sludge as a possible alternative or a compliment to sharp sand in concrete mix design, driven by the fact the "reuse" of dredged waste products should not be solely limited to the use of reclaimed water, but also the potentiality of sludge as a useful material in construction should be considered, while having in mind the disposal problem of sludge and the associated environmental concerns.

Tests show that concrete made from sludge have higher compacting factor compared to sand concrete which can be attributed to the clay composition of sludge but the compressive strength of the sludge concrete is very low. Hence, comparing the properties, such as workability, water absorption capacity, density and shrinkage of sludge concrete against sand concrete, it can be concluded that sand is a better material for concrete than sludge.

REFERENCES

Alleman, J.E., Bryan E.H, Stumm T.A., Marlow W.W. and Hocevar, R.C. "Sludge-Amended Brick Production: Applicability for Metal-Laden Residues". Water Science and Technology, Volume 22, Number 12. 309-317, 1990.

American Society for Testing and Materials (ASTM). Standard Test Method for Laboratory Determination of Water (moisture) Content of Soil and Rock by Mass, Designation D2216-98. American Society for Testing and Materials. West Conshohocken, PA. 3-25, 1998.

B.S 1377. "Methods of Tests for Soils for Civil Engineering Purposes". British Standard institution London, 1975.

Snow, K.J. "Digestion, Biosolids Treatment and Management: Processes for Beneficial Use". Edited by Girovich, M.J. New , 23 – 37. York: Marcel Dekker Inc., 1996.

Tay, J. and Show, K. "Properties of Cement Made from Sludge". Journal of Environmental Engineering, Volume117, 236-246, 1985.

Vandorpe S. "Mobile Dredging Sludge Treatment Installation at Hourpes (Belgium): Example of an Innovative Treatment Combining Mechanical Dewatering and Lime". 1-2, 2005.

Wilby, C.B. Concrete Materials and Structures. Cambridge, MA: Cambridge University Press, 22- 23, 1991.

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